# D E C L A R A T I O N

In the matter of U.S. Patent Application Ser. No. 10/565,574 in the name of Hiroyuki TOKUDA et al.

I, Yasutaka ENOKI, of Kyowa Patent and Law Office, 2-3, Marunouchi 3-Chome, Chiyoda-Ku, Tokyo-To, Japan, declare and say:

that I am thoroughly conversant with both the Japanese and English languages; and,

that the attached document represents a true English translation of Japanese Patent Application No. 2003-199983 filed on July 22, 2003.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Title of the Invention: RADIATION CURABLE RESIN COMPOSITION FOR LENS SHEET AND LENS SHEET

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| Abstract | 1 |

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[TITLE OF DOCUMENT] SPECIFICATION

[TITLE OF INVENTION] ACTINIC-ENERGY-RAY-CURABLE RESIN COMPOSITION FOR LENS SHEET AND LENS SHEET

[SCOPE OF CLAIMS]

[CLAIM 1] An actinic-energy-ray-curable resin composition for a lens sheet, characterized by comprising:

an epoxy (meth)acrylate (a);

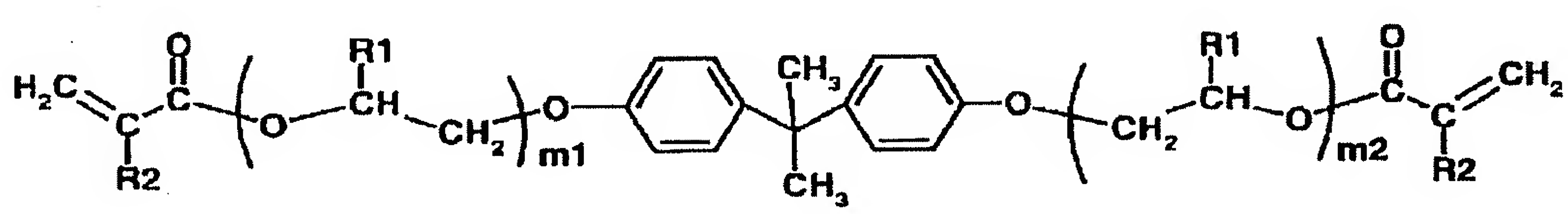
a bifunctional (meth)acrylate (b);

a monofunctional (meth)acrylate (c); and

a thermoplastic resin (d),

wherein the bifunctional (meth)acrylate (b) comprises:

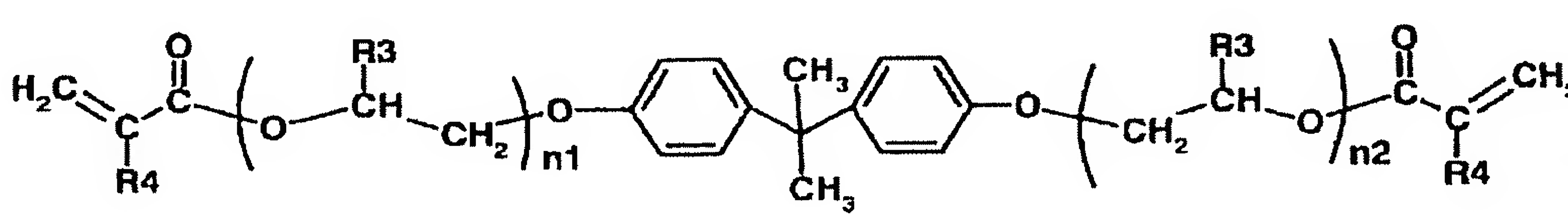
a (meth)acrylate (b1) expressed by the general formula (1) described below,



(1)

(wherein, R1, R2 denote either hydrogen atoms or a methyl group, and a mean value of m1+m2 is 1 to 5);

a (meth)acrylate (b2) expressed by the general formula (2) described below,



(2)

(wherein, R3, R4 denote either hydrogen atoms or a methyl group, and a mean value of n1+n2 is 8 to 20); and

a (meth)acrylate (b3) of an aliphatic dihydric alcohol having an alkylene oxide structure.

[CLAIM 2] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 1, wherein a mass ratio (b1)/(b2) of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 20/80 to

80/20.

[CLAIM 3] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 2, wherein a mass ratio (b3)/[(b1)+(b2)] of the (meth)acrylate (b3) to the sum of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 15/85 to 70/30.

[CLAIM 4] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 1, wherein the acrylate (b3) is a (meth)acrylate (b31) of an aliphatic dihydric alcohol having a propylene oxide structure.

[CLAIM 5] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 4, wherein a mass ratio (b1)/(b2) of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 20/80 to 80/20.

[CLAIM 6] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 1, wherein a mass ratio (b3)/[(b1)+(b2)] of the (meth)acrylate (b3) to the sum of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 15/85 to 70/30, and wherein the thermoplastic resin (d) is a polyurethane-type resin.

[CLAIM 7] The actinic-energy-ray-curable resin composition for the lens sheet according to claim 1, wherein a mass ratio (b3)/[(b1)+(b2)] of the (meth)acrylate (b3) to the sum of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 15/85 to 70/30, and wherein the thermoplastic resins (d) is a thermoplastic resin comprising 60mass% or more of an urethane-type resin having a glass transition temperature ranging from -70°C to 0°C.

[CLAIM 8] The actinic-energy-ray-curable resin composition for the lens sheet according to any one of claims 1 to 7, wherein the epoxy (meth)acrylate (a) is a (meth)acrylate of a bisphenol-type epoxy resin.

[CLAIM 9] The actinic-energy-ray-curable resin composition for the

lens sheet according to any one of claims 1 to 7, wherein in 100 parts by mass of the sum of the epoxy (meth)acrylate (a), the bifunctional (meth)acrylate (b), the monofunctional (meth)acrylate (c) and the thermoplastic resin (d), the content of the epoxy (meth)acrylate (a) ranges from 20 to 70 parts by mass, the content of the bifunctional (meth)acrylates (b) ranges from 5 to 60 parts by mass, the content of the monofunctional (meth)acrylate (c) ranges from 5 to 40 parts by mass, and the content of the thermoplastic resin (d) ranges from 0.5 to 10 parts by mass.

[CLAIM 10] A lens sheet, characterized in that a lens-shaped resin layer formed by curing the actinic-energy-ray-curable resin composition for the lens sheet according to any one of claims 1 to 9 is provided on a plastic substrate.

[CLAIM 11] The lens sheet according to claim 10, wherein the plastic substrate is a substrate comprising an acrylate resin, a polystyrene resin, a polyester resin or a polycarbonate resin.

[CLAIM 12] The lens sheet according to claims 10 or 11, wherein the lens sheet is a Fresnel lens sheet.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field to Which the Invention Pertains]

This invention relates to an actinic-energy-ray-curable resin composition for lens sheet use which is capable of being used suitably for manufacturing a lens sheet, such as a Fresnel lens sheet or a lenticular lens sheet, having a structure in which a molded layer performing a lens function and made of a cured resin material is provided on a plastic substrate, and also to a lens sheet produced by curing the resin composition into a lens shape on a plastic substrate.

[0002]

[Prior Art]

An example conventionally known as a transmission type screen such as is used in projection TV sets has a structure using a

combination of a Fresnel lens sheet for converting diffuse light from a light source such as a CRT into parallel beams to be sent to the viewers, and a lenticular lens sheet which performs the function of distributing light only within the range which the viewers watch, for effective use of a fixed amount of light.

[0003]

A method proposed for forming and processing these lens sheets is the effective formation of a lens sheet in a short time by the application of an actinic energy ray to form a lens layer which has microstructure and is made of an actinic-energy-ray-curable resin composition, on a plastic substrate. Since the actinic-energy-ray-curable resin composition used for these lens sheets has the characteristics of a high elastic coefficient and a high refractive index, the example of using an epoxy (meth) acrylate resin composite has been reported.

[0004]

The requirements for a lens layer of microstructure made of such an actinic-energy-ray-curable resin composition are excellent shape retention withstanding external forces locally applied during the manufacturing process and the like or a change in environment temperature, a high mechanical strength such that disadvantages such as fracture and chipping are not produced upon application of an impact or the process of cutting the sheet, a satisfactory degree of adhesion to the plastic substrate, a high refractive index, and the like.

[0005]

An example known as an actinic-energy-ray-curable resin composition for meeting such requirements is a ultraviolet-curable resin composition for a transmission type screen which includes, in specific proportions as essential ingredients, a bisphenol-A type epoxy (meth)acrylate, a bifunctional reactive monomer, a monofunctional reactive monomer and a photopolymerization initiator. This composition has the advantages of providing a cured material with a satisfactory degree of adhesion to a plastic substrate and a high refractive index (see Patent Document 1, for example).

[0006]

Another known example is an ionization-radiation-curable resin

composition for a Fresnel lens including a bisphenol-A type epoxy (meth)acrylate, a monofunctional (meth)acrylate such as phenoxy ethyl acrylate, a bifunctional (meth)acrylate such as bisphenol-A tetrapropoxydiacrylate, and a polymer such as an acrylate resin or a urethane resin. This composition has the advantages of providing a cured material with a high refractive index, outstanding wear resistance and outstanding adhesion to a substrate (see Patent Document 2, for example).

[0007]

[Patent Document 1] JP-A-H5-287040 (pp. 3-6)

[Patent Document 2] JP-A-H11-240926 (pp. 3-4)

[0008]

[Problem to Be Solved by the Invention]

However, a cured material made of an ultraviolet-curable resin composition for a transmission type screen, which is described in Patent Document 1, has the disadvantages of a propensity for occurrence of creep deformation even after the cure reaction and insufficient shape retention, because a high proportion of a monofunctional reactive monomer from 40mass% to 70mass% causes a loosely crosslinked structure resulting from the reaction between a bisphenol-A type epoxy (meth)acrylate and a bifunctional reactive monomer, resulting in a low crosslink density.

[0009]

Further, a cured material made of ionization-radiation-curable resin composition for a Fresnel lens, which is described in Patent Document 2, can exhibit shape recovery properties and shape retention to a certain degree by means of control of a proportion of the content of a polymer component, e.g. a low glass transition temperature polymer such as a polyester polyurethane resin (glass transition temperature Tg: -20°C), but shape recovery properties and shape retention are insufficient. For this reason, it is difficult to provide the shape recovery properties and the shape retention while concurrently maintaining the moldability such as the casting efficiency of infusing an actinic-energy-ray-curable resin composition between the mother mold and the plastic substrate and the shape reproducibility provided by the spread of the resin into the intricate details of the mother mold.

[0010]

To solve the problems, it is an object of the present invention to provide an actinic-energy-ray-curable resin composition for lens sheets use which is outstanding in adhesion to a plastic substrate, shape recovery properties, mechanical strength and moldability, and further shows a high refractive index, and to provide a lens sheet using the resin composition.

[0011]

[Means for Solving the Problem]

As a result of energetically redoubling research of the inventors into a solution of the above problems, the inventors have arrived at this invention by establishing the fact that an actinic-energy-ray-curable resin composition, which has satisfactory adhesion to a plastic substrate, outstanding shape recovery properties, and adequate moldability such as casting efficiency and shape reproducibility, and moreover shows a high refractive index, and which thus is suitable for use as an actinic-energy-ray-curable resin composition for lens sheets, can be made by use, with an epoxy (meth)acrylate and a monofunctional (meth)acrylate, of a (meth)acrylate expressed by the general formula (1) described below, a (meth)acrylate expressed by the general formula (2) described below and a (meth)acrylate of an aliphatic dihydric alcohol having an alkylene oxide structure in combination, as the bifunctional (meth)acrylate, and by adding a thermoplastic resin, as a polymer, thereto.

[0012]

Specifically, the present invention provides an actinic-energy-ray-curable resin composition for lens sheet use which is characterized by comprising:

an epoxy (meth)acrylate (a);

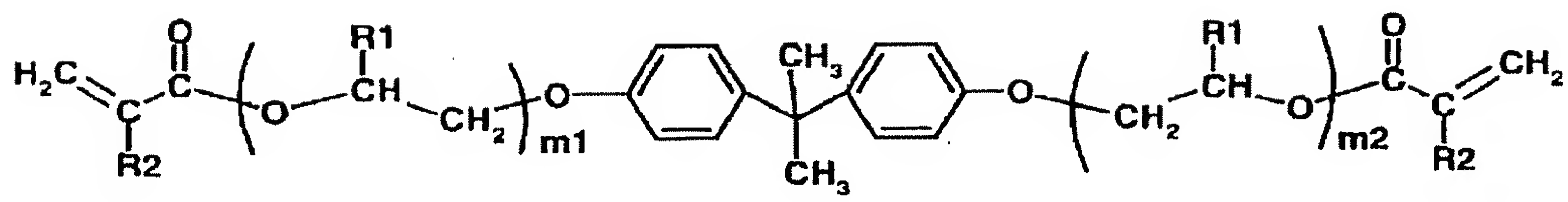
a bifunctional (meth)acrylate (b);

a monofunctional (meth)acrylate (c); and

a thermoplastic resin (d),

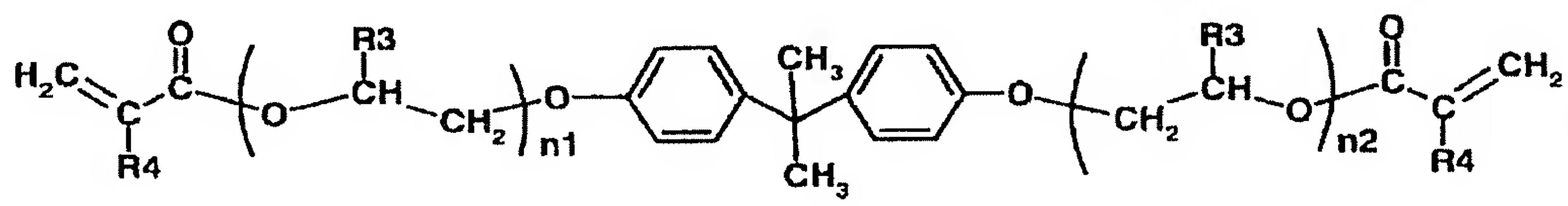
wherein the bifunctional (meth)acrylate (b) comprises:

a (meth)acrylate (b1) expressed by the general formula (1) described below,

 (1)

(wherein, R1, R2 denote either hydrogen atoms or a methyl group, and a mean value of m1+m2 is 1 to 5);

a (meth)acrylate (b2) expressed by the general formula (2) described below,

 (2)

[0013]

(wherein, R3, R4 denote either hydrogen atoms or a methyl group, and a mean value of n1+n2 is 8 to 20); and

a (meth)acrylate (b3) of an aliphatic dihydric alcohol having an alkylene oxide structure, and wherein the thermoplastic resin (d) has a glass transition temperature of 20°C or less.

[0014]

Further, the present invention provides a lens sheet characterized in that a lens-shaped resin layer resulting from curing the lens-sheet-application actinic-energy-ray-curable resin composition is provided on a plastic substrate.

[0015]

[Mode for Carrying Out the Invention]

The present invention will be described below in detail.

Epoxy (meth)acrylate (a) used in the present invention comprises, for example, an epoxy (meth)acrylate having two or more (meth)acryloyl groups obtained by the reaction between an epoxy resin having two or more epoxy groups and (meth)acrylic acid. As the specific examples of the epoxy (meth)acrylate used are (meth)acrylate of an aliphatic epoxy resin, (meth)acrylate of a bisphenol-type epoxy resin, (meth)acrylate of a hydrogenated bisphenol-type epoxy resin, (meth)acrylate of a novolac-type epoxy resin, (meth)acrylate of an epoxy resin having a naphthalene skeleton, and the like and any

mixture of them.

Note that in the present invention (meth)acrylate means one or both of acrylate and methacrylate. Similarly, (meth)acrylic acid, (meth)acryloyl mean one or both of acrylic acid and methacrylic acid, and (meth)acryloyl means one or both of acryloyl mean and methacryloyl.

[0016]

An epoxy (meth)acrylate having a cyclic structure and two or more (meth)acryloyl groups, of the above examples of the epoxy (meth)acrylate (a) is preferable for achievement of excellent mechanical strength and therefore an increase in refractive index. As the specific examples of this epoxy (meth)acrylate are (meth)acrylate of a bisphenol-A type epoxy resin, (meth)acrylate of a bisphenol-F type epoxy resin, (meth)acrylate of a bisphenol-A type epoxy resin partially substituted by halogen, (meth)acrylate of a bisphenol-F type epoxy resin partially substituted halogen, (meth)acrylate of hydrogenated bisphenol-A type epoxy resin, any mixture of them, and the like. Of these, the (meth)acrylate of a bisphenol-A type epoxy resin is particularly preferable.

[0017]

Next, the bifunctional (meth)acrylate (b) used in the present invention comprises a (meth)acrylate (b1) expressed by the above general formula (1), a (meth)acrylate (b2) expressed by the above general formula (2) and a (meth)acrylate (b3) of an aliphatic dihydric alcohol having an alkylene oxide structure, and, optionally, another bifunctional (meth)acrylate (b4).

[0018]

As the examples of the (meth)acrylate (b1) expressed by the general formula (1), in the bifunctional (meth)acrylates (b) used in the present invention, are di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 1 to 5 [the mean value of m1+m2 in the general formula (1)], di(meth)acrylate of propylene oxide modified bisphenol-A with an average number of added moles of propylene oxide ranging from 1 to 5, di(meth)acrylate of ethylene-oxide propylene-oxide modified bisphenol-A with an average number of added moles of both ethylene

oxide and propylene oxide ranging from 1 to 5, and the like.

[0019]

Preferable examples of the above examples of the (meth)acrylate compound (b1) are di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 3 to 5 and di(meth)acrylate of propylene oxide modified bisphenol-A with an average number of added moles of propylene oxide ranging from 3 to 5, because they can achieve excellent mechanical strength, and a particularly preferable example is di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 3 to 4.

[0020]

As the examples of the marketed products of the (meth)acrylate compound (b1) used are ARONIX M-210, ARONIX M-211B (which are produced by Toagosei Corporation), LIGHT-ACRYLATE BP-4EA, LIGHT-ACRYLATE BP-4PA, LIGHT-ESTER BP-2EM [which are produced by KYOEISHA CHEMICAL Corporation], NK ESTER A-BPE-4, NK ESTER BPE-100, NK ESTER BPE-200 [which are produced by Shin-nakamura Chemical Corporation], KAYARAD R-55 [produced by Nippon Kayaku Corporation], BEAM SET 750[produced by Arakawa Chemicals Industries ], SR-348, SR-349, SR-601 [which are produced by Kayaku Sartomer Company], new Frontier BPE-4, new Frontier BPE-4 [which are produced by Dai-ichi Kogyo Seiyaku Corporation], Viscoat#700 [produced by Osaka organic chemistry industry Corporation], Photomer 4028 [produced by San Nopco Limited], Ebecryl 150, Ebecryl 1150, BPA(E03)DMA [which are produced by Daicel UCB], BLEMMER-ADBE-200, BLEMMER-PDBE-200, BLEMMER ADBP series, BLEMMER PDBP series, BLEMMER ADBEP series, BLEMMER PDBEP series [which are produced by NOF CORPORATION], and the like.

[0021]

As the examples of the (meth)acrylate (b2) expressed by the general formula (2), in the bifunctional (meth)acrylate (b) used in the present invention, are di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 8 to 20 [the mean value of n1+n2 in the general formula (2)], di(meth)acrylate of propylene oxide modified bisphenol-A with an

average number of added moles of propylene oxide ranging from 8 to 20, di(meth)acrylate of ethylene-oxide propylene-oxide modified bisphenol-A with an average number of added moles of both ethylene oxide and propylene oxide ranging from 8 to 20, and the like.

[0022]

Preferable examples of the above examples of the (meth)acrylate (b2) are di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 8 to 16 and di(meth)acrylate of propylene oxide modified bisphenol-A with an average number of added moles of propylene oxide ranging from 8 to 16, because they can achieve favorite shape recovery properties. A particularly preferable example is di(meth)acrylate of ethylene oxide modified bisphenol-A with an average number of added moles of ethylene oxide ranging from 9 to 12.

[0023]

As the examples of the marketed products of the (meth)acrylate (b2) are SR-602, SR-480 [which are produced by Kayaku Sartomer Company], new Frontier BPE-10, new Frontier BPE-20, BPEM-10 [which are produced by Dai-ichi Kogyo Seiyaku Corporation], Photomer 4025 [produced by San Nopco Limited], NK ESTER BPE-500 [produced by Shin-nakamura Chemical Corporation], FANCRYL FA-321M [which are produced by Hitachi Chemical Corporation], BLEMMER-PDBE-400, BLEMMER 43PDBP-800B [which are produced by NOF CORPORATION], and the like.

[0024]

As the examples of the (meth)acrylate (b3) of an aliphatic dihydric alcohol having an alkylene oxide structure, in the bifunctional (meth)acrylate (b) used in the present invention, are: ethylene glycol di(meth)acrylate; propylene glycol di(meth)acrylate; polyethylene glycol di(meth)acrylate, such as diethylene glycol di(meth)acrylate, triethylene glycol di(meth)acrylate, tetraethylene glycol di(meth)acrylate, heptaethylene glycol di(meth)acrylate; polypropylene glycol di(meth)acrylate such as dipropylene glycol di(meth)acrylate, tripropylene glycol di(meth)acrylate, tetrapropylene glycol di(meth)acrylate, and heptapropylene glycol di(meth)acrylate; di(meth)acrylate, such as 1,3-butylene glycol di(meth)acrylate,

1,4-butylene glycol di(meth)acrylate, 1,6-hexamethylene glycol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate; neopentylglycol di(meth)acrylate, hydroxypivalate neopentylglycol di(meth)acrylate, and a compound including caprolactone added to hydroxypivalic acid neopentyl glycol; a compound to which two molecules of (meth)acrylic acid are linked through ester bond, such as neopentylglycol adipate di(meth)acrylate; and the like.

[0025]

A preferable example of the above examples of the (meth)acrylate (b3) is a (meth)acrylate (b31) of an aliphatic dihydric alcohol having a propylene oxide as the alkylene oxide structure because a cured material obtained will have a satisfactory degree of adhesion to a plastic substrate.

[0026]

As the examples of the (meth)acrylate (b31) of an aliphatic dihydric alcohol having a propylene oxide structure are propylene glycol di(meth)acrylate; di(meth)acrylate of polypropylene glycol di(meth)acrylate such as propylene glycol di(meth)acrylate, tripropylene glycol di(meth)acrylate, tetrapropylene glycol di(meth)acrylate and heptapropylene glycol di(meth)acrylate; and the like.

[0027]

A mass ratio (b1)/(b2) of the (meth)acrylate (b1) and the (meth)acrylate (b2), which are di(meth)acrylates having two bisphenol-A skeletons different in number of added moles of alkylene oxide, preferably ranges from 20/80 to 80/20, more preferably, from 30/70 to 70/30, in order to obtain a cured material having a desirable combination of the adhesion and the mechanical strength.

[0028]

Further, a proportion of the (meth)acrylate (b3) used of an aliphatic dihydric alcohol having an alkylene oxide structure, in the bifunctional (meth)acrylate (b), for example, a mass ratio of (b3)/[(b1)+(b2)] of the (meth)acrylate (b3) to the total of the (meth)acrylate (b1) and the (meth)acrylate (b2) ranges from 15/85 to 70/30, preferably, 25/75 to 60/40, in order to obtain a cured material having satisfactory degrees of adhesion and mechanical strength.

[0029]

Among the bifunctional (meth)acrylates (b) used in the present invention, another bifunctional (meth)acrylate (b4) is used in combination as necessary to serve the purpose of fine-adjusting the viscosity and the refractive index, for example. The examples of the bifunctional (meth)acrylate (b4) used include, for example: a compound in which two molecules of (meth)acrylic acid is attached through ester bond to a compound having two hydroxyl groups, such as ethylene oxide adduct of halogenated bisphenol-A, propylene oxide adduct of halogenated bisphenol-A, ethylene oxide adduct of bisphenol-F, propylene oxide adduct of bisphenol-F, ethylene oxide adduct of halogenated bisphenol-F, propylene oxide adduct of halogenated bisphenol-F, ethylene oxide adduct of bisphenol-S, propylene oxide adduct of bisphenol-S, ethylene oxide adduct of halogenated bisphenol-S, propylene oxide adduct of halogenated bisphenol-S, tricyclodecanedimethylol;

[0030]

Sulfur-containing compound such as bis[4-(meth)acryloyloxyphenyl]- sulfide, bis[4-(meth)acryloyloxyethoxyphenyl]-sulfide, bis[4-(meth)acryloyloxypentaethoxyphenyl]-sulfide, bis[4-(meth)acryloyloxyethoxy-3-phenylphenyl]-sulfide, bis[4-(meth)acryloyloxyethoxy-3,5-dimethylphenyl]-sulfide, and bis(4-(meth)acryloyloxyethoxyphenyl)sulfone; di[(meth)acryloyloxyethoxy]phosphate; and the like.

[0031]

A proportion of the another bifunctional (meth)acrylate (b4) used with respect to 100 parts by mass of the total amount of the bifunctional (meth)acrylates (b) is typically 30 or less parts by mass, preferably 1 to 20 parts by mass.

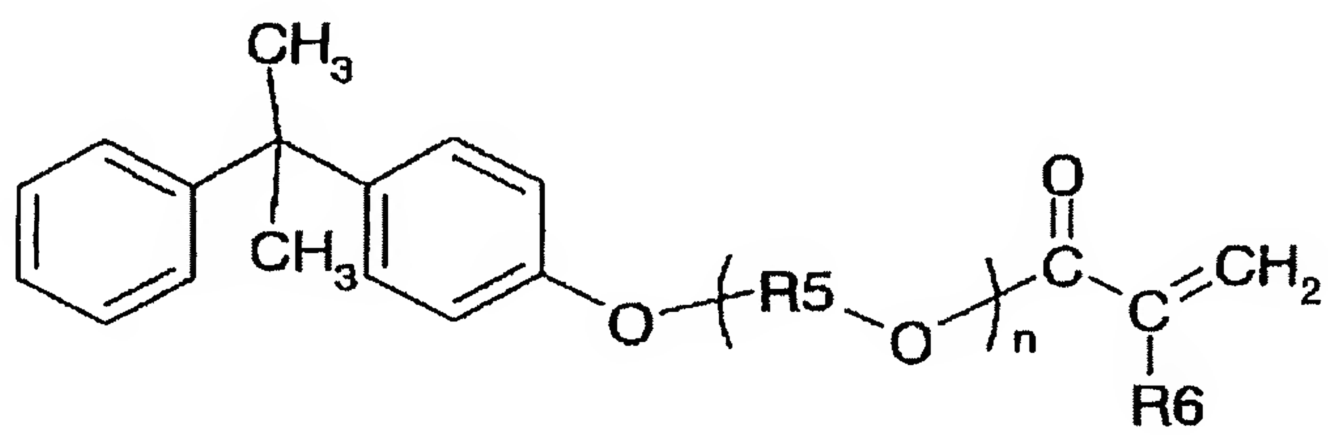
[0032]

As the examples of the monofunctional (meth)acrylate (c) used in the present invention are monofunctional (meth)acrylate having a cyclic structure, (meth)acrylate with an alkyl group having carbon numbers ranging from 1 to 22, (meth)acrylate having a hydroxyalkyl group, lactone modified hydroxyethyl (meth)acrylate, (meth)acrylate

having a polyalkylene glycol group, phosphoethyl (meth)acrylate, N,N-dialkylaminoalkyl (meth)acrylate, and the like. A preferable example of the above examples is the monofunctional (meth)acrylate having a cyclic structure for achievement of high refractive index as required without a decrease in elastic coefficient.

[0033]

As the examples of the monofunctional (meth)acrylate (c1) having a cyclic structure are: benzoyloxyethyl (meth)acrylate, benzyl (meth)acrylate, phenylethyl (meth)acrylate, phenoxyethyl (meth)acrylate, phenoxy diethylene glycol (meth)acrylate, and 2-hydroxy-3-phenoxypropyl (meth)acrylate; 2-phenyl-2-(4-(meth)acryloyloxyphenyl)propane, expressed by the following general formula (3),




(3)

(wherein R5 is a hydrocarbon radical having 1 to 5 carbon atoms, R6 is either a hydrogen atom or an ethyl group, and n is a mean value of zero to 3 ),
2-phenyl-2-(4-(meth)acryloyloxyethoxyphenyl)propane,
2-phenyl-2-(4-(meth)acryloyloxypropoxyphenyl)propane, and the like;

[0034]

monofunctional (meth) acrlate having an aromatic ring, such as chlorophenyl (meth)acrylate, bromophenyl (meth)acrylate, chlorobenzyl (meth)acrylate, bromobenzyl (meth)acrylate, chlorophenylethyl (meth)acrylate, bromophenylethyl (meth)acrylate, chlorophenoxyethyl (meth)acrylate, bromophenoxyethyl (meth)acrylate, 2,4,6-trichlorophenyl (meth)acrylate, 2,4,6-tribromophenyl (meth)acrylate, 2,4,6-trichlorobenzyl (meth)acrylate, 2,4,6-tribromobenzyl (meth)acrylate, 2,4,6-trichlorophenoxyethyl (meth)acrylate,

2,4,6-tribromophenoxyethyl (meth)acrylate, o-phenylphenol(poly)ethoxy (meth)acrylate and p-phenylphenol(poly)ethoxy(meth)acrylate;

[0035]

(meth)acrylates having an alicyclic structure or a hetrocyclic structure, such as cyclohexyl (meth)acrylate, isobornyl (meth)acrylate, dicyclopentyl (meth)acrylate, dicyclopentenyloxyethyl (meth)acrylate, tetrahydrofurfuryl (meth)acrylate and glycidyl cyclocarbonate (meth)acrylate; and the like.

[0036]

Note that, a part of the monofunctional (meth)acrylate (c), for example 1mass % to 40mass % of the monofunctional (meth)acrylate (c), can be substituted by a vinyl compound having an aromatic ring structure or heterocycle structure. Among the examples of the vinyl compound having the aromatic ring structure are styrene, α-methylstyrene, and the like. As the examples of the vinyl compound having the heterocycle structure are N-vinylpyrrolidone, N-vinylcaprolactam, acryloyl morpholine, and the like.

[0037]

The monofunctional (meth)acrylates having an aromatic ring of the above examples can be suitably used because the mechanical strength and high refractive index are not impaired.

[0038]

As the examples of the thermoplastic resin (d) used in the present invention are: an acrylic-type resin such as a polymethyl methacrylate resin and a methyl methacrylate copolymer; a polyurethane-type resin; a polyester-type resin; a styrene-type resin such as polystyrene and a styrene-methyl methacrylate copolymer; a polybutadiene-type resin such as polybutadiene and a butadiene-acrylonitrile copolymer; a thermoplastic epoxy resin such as a phenoxy resin; and the like. The polyurethane-type resin of the above examples is preferable because it can achieve satisfactory shape recovery properties and exhibits outstanding compatibility with the epoxy (meth)acrylate (a), the bifunctional (meth)acrylates (b) and the like.

[0039]

Further, a preferable type of the above-described thermoplastic resins (d) has a glass transition temperature (Tg) of 20°C or less, and a thermoplastic resin having Tg ranging from -70°C to 0°C is particularly preferable because it functions to enhance the effect of improving the shape recovery properties. The polyurethane-type resin of these thermoplastic resins having Tg ranging from -70°C to 0°C is more preferable, and a polyurethane-type resin of Tg ranging from -70°C to -43°C is particularly preferable. For the sake of reference, when an acrylic-type resin substrate is used as the plastic substrate and the polyurethane-type resin is used as the thermoplastic resin (d), the adhesion to the acrylic-type resin substrate is improved. For this reason, an acrylic-type resin can be used in combination with the polyurethane-type resin. When the acrylic-type resin is used, the percentage of the urethane-type resin content is preferably 60mass% or more.

[0040]

Note that, in the present invention, values of the glass transition temperature (Tg) of the thermoplastic resin (d) are defined as values obtained from data concerning measurements made by use of a differential scanning calorimeter (DSC) on condition that a rate of temperature rise is 10°C/min. and measurement temperature ranges from -100°C to 150°C.

[0041]

In the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, for achievement of satisfactory adhesion to the plastic substrate, favorable shape recovery properties of a cured material, a high mechanical strength and a high refractive index, 100 parts by mass of the total amount of the epoxy (meth)acrylate (a), bifunctional (meth)acrylate (b), monofunctional (meth)acrylate (c), and thermoplastic resin (d) comprise 20 to 70 parts by mass of the epoxy (meth)acrylate (a), 5 to 60 parts by mass of the total amount of the bifunctional (meth)acrylate (b), 5 to 40 parts by mass of the monofunctional (meth)acrylate (c), and 0.5 to 10 parts by mass of the thermoplastic resin (d), and further, particularly preferably comprise 30 to 50 parts by mass of the epoxy (meth)acrylate (a), 25 to 45 parts by mass of the total amount of the bifunctional (meth)acrylate

(b), 15 to 35 parts by mass of the monofunctional (meth)acrylate (c), and 1 to 10 parts by mass of the thermoplastic resin (d).

[0042]

The essential ingredients of actinic-energy-ray-curable resin composition for lens sheet use according to the present invention are the four ingredients of the aforementioned (a), (b), (c) and (d). However, addition of a multifunctional, trifunctional or more than trifunctional, (meth)acrylate (e) is desirable because the crosslink density is increased and the degrees of shape retention and mechanical strength of a resulting cured material are increased.

[0043]

As the examples of the multifunctional (meth)acrylate (e) used are multifunctional (meth)acrylate such as trimethylolpropane tri(meth)acrylate, pentaerythritol tri(meth)acrylate, glycerin tri(meth)acrylate, tri(acryloyloxyethyl)isocyanurate, pentaerythritol tetra(meth)acrylate, dipentaerythritol hexa(meth)acrylate, dipentaerythritol penta(meth)acrylate, tri[(meth)acryloyloxyethoxy]phosphate.

[0044]

Various types of multifunctional (meth)acrylate can be used as the multifunctional (meth)acrylate (e) as long as it is trifunctional or more than trifunctional (meth)acrylate, but the use of (meth)acrylate (e) of aliphatic polyhydric alcohol having a propylene oxide structure of them is desirable because it becomes possible to increase the crosslink density without impairment of adhesion to the plastic substrate.

[0045]

As the examples of the (meth)acrylate (e1) of aliphatic polyhydric alcohol having a propylene oxide structure is a compound having ester linkage of (meth)acrylic acid created after 1 mol to 20 mol propylene oxide is added to trifunctional or more than trifunctional polyhydric alcohol such as trimethylolpropane, ditrimethylolpropane, pentaerythritol, dipentaerythritol, tetramethylolmethane or the like. Of them, a compound having ester linkage of (meth)acrylic acid created after 3 mol to 9 mol propylene oxide is added to aliphatic polyhydric alcohol is preferable.

[0046]

When the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention includes additionally the multifunctional (meth)acrylate (e), for achievement of enhancement in the crosslink density, satisfactory adhesion to the plastic substrate, favorable shape recovery properties of the cured resin layer, a high mechanical strength and a high refractive index, 100 parts by mass of the total amount of the epoxy (meth)acrylate (a), bifunctional (meth)acrylate (b), monofunctional (meth)acrylate (c), armoplastic resin (d) and the multifunctional (meth)acrylate (e) comprise 20 to 70 parts by mass of the epoxy (meth)acrylate (a), 5 to 60 parts by mass of the bifunctional (meth)acrylate (b), 5 to 40 parts by mass of the monofunctional (meth)acrylate (c), 0.5 to 10 parts by mass of the thermoplastic resin (d), and 1 to 10 parts by mass of the multifunctional (meth)acrylate (e), and, particularly preferably comprises 30 to 50 parts by mass of the epoxy (meth)acrylate (a), 25 to 45 parts by mass of the bifunctional (meth)acrylate (b), 15 to 35 parts by mass of the monofunctional (meth)acrylate (c), 1 to 10 parts by mass of the thermoplastic resin (d), and 1 to 8 parts by mass of the multifunctional (meth)acrylate (e).

[0047]

A desirable refractive index of the cured actinic-energy-ray-curable resin composition for lens sheet use according to the present invention composed of the foregoing components is 1.55 or more. Thereby, when a lens sheet is manufactured, even if the depth of the lens shape is decreased to make mold release characteristics from the mother mold, the lens sheet obtained exhibits excellent optical performance.

[0048]

For the purpose of uniform application to a mother mold and further of achievement of reproduction of the mother mold having microstructure, the viscosity of the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention (the viscosity measured at 25ºC by an E-type rotational viscometer) ranges desirably from 1,000mPa.s to 30,000mPa.s at 25ºC, particularly preferably, from 3,000mPa.s to 23,000mPa.s. If the viscosity of the composition is out of the above range, the resin composition can be

used by means of a method of controlling the temperature of the resin composition to adjust the viscosity.

[0049]

When a lens sheet with fine patterning has been molded and thereafter, is removed from the mother mold, external forces are often applied to the lens-sheet shape to deform it. In the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, for easy recovery from the deformation, the temperature [T(max)] representing the maximum value of the mechanical loss tangent obtained through dynamic viscoelasticity measurement made at a frequency $1H_2$ on the cured material which is cured by an actinic energy ray is desirably at 50°C or less, particularly preferably, within a range from 30°C to 50°C.

[0050]

For the sake of reference, since dynamic viscoelasticity measurement is typically susceptible to the film thickness of a sample film, the values in the dynamic viscoelasticity measurement in the present invention are defined as values obtained from data derived from the measurement in a temperature range from -30°C to 12°C out of the data on the results of measurement which is made by use of a solid viscoelasticity measuring apparatus employing a distortion control method (e.g. RSA-2 produced by Rheometrics Corporation) on condition that a film used has a film thickness of 200±25μm and a size of 6mm×35mm, a frequency is 1Hz, a load distortion is 0.05%, a rate of temperature rise is 3°C/min., and a measurement temperature is -50°C to 150°C.

[0051]

The actinic-energy-ray-curable resin composition for lens sheet use according to the present invention is cured by application of the actinic energy ray. The actinic energy ray means a ray having the energy quantum that allows polymerization, crosslinking of molecules of an electromagnetic wave or a charged particle ray. Examples of such a ray include the electromagnetic wave such as visible light, ultraviolet light and X rays and the charged particle ray such as electron rays. The practically most-used ray of the above examples is visible light, ultraviolet light or electron rays.

[0052]

In the ultraviolet light, a ultra-high pressure mercury lamp, high-pressure mercury lamp, low-pressure mercury lamp, carbon arc, blacklight lamp, metal halide lamp and the like can be used for the light source.

[0053]

When the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention is cured by the visible light or ultraviolet light, the resin composition includes photo(polymerization) initiator dissociating to produce radical by the application of ultraviolet light or visible light.

[0054]

Various types of photopolymerization initiator that dissociates by the application of light to produce radical can be used as such a photo(polymerization) initiator. As the examples of the photo(polymerization) initiator are benzophenones, such as benzophenone, 3,3'-dimethyl-4-methoxybenzophenone, 4,4'-bisdimethylaminobenzophenone, 4,4'-bisdiethylaminobenzophenone, 4,4'-dichlorobenzophenone, Michler's ketone and 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone; xanthones and thioxanthones, such as xanthone, thioxanthone, 2-methylthioxanthone, 2-chlorothioxanthone and 2,4-diethylthioxanthone; acloin ethers, such as benzoin, benzoin methyl ether, benzoin ethyl ether and benzoin isopropyl ether; α-diketones, such as benzyl and diacetyl; sulfides, such as tetramethylthiuram disulfide and p-tolyl disulfide; benzoic acids such as 4-dimethylaminobenzoic acid and ethyl 4-dimethylaminobenzoate;

[0055]

and also, 3,3'-carbonyl-bis(7-diethylamino)coumarin, 1-hydroxycyclohexyl phenyl ketone, 2,2'-dimethoxy-1,2-diphenylethan-1-one, 2-methy-1-[4-(methylthio)phenyl]-2-morpholinopropan-1-one, 2-benzyl-2-dimethylamino-1-(4-morpholinophenyl)-butan-1-one, 2-hydroxy-2-methyl-1-phenylpropan-1-one, 2,4,6-trimethylbenzoyldiphenylphosphine oxide,

bis(2,4,6-trimethylbenzoyl)phenylphosphine oxide, 1-[4-(2-hydroxyethoxy)phenyl]-2-hydroxy-2-methyl-1-propan-1-one, 1-(4-isopropylphenyl)-2-hydroxy-2-methylpropan-1-one, 1-(4-dodecylphenyl)-2-hydroxy-2-methylpropan-1-one, 4-benzoyl-4'-methyldimethyl sulfide, 2,2'-diethoxyacetophenone, benzyl dimethyl ketal, benzyl-β-methoxyethylacetal, methyl o-benzoylbenzoate, bis(4-dimethylaminophenyl)ketone, p-dimethylaminoacetophenone, α,α-dichloro-4-phenoxyacetophenone, pentyl-4-dimethylamino benzoate, 2-(o-chlorophenyl)-4,5-diphenylimidazolyl dimer, 2,4-bis-trichloromethyl-6-[di-(ethoxycarbonylmethyl)amino]phenyl-S-triazine , 2,4-bis-trichloromethyl-6-(4-ethoxy)phenyl-S-triazine, 2,4-bis-trichloromethyl-6-(3-bromo-4-ethoxy)phenyl-S-triazineanthra quinone, 2-t-butylanthraquinone, 2-amylanthraquinone, β-chloroanthraquinone and the like.

[0056]

As the examples of the marketed products of the photo(polymerization) initiator are Irgacure-184, -149, -261, -369, -500, -651, -754, -784, -819, -907, -1116, -1300, -1664, -1700, -1800, -1850, -2959, -4043, Darocur-1173 (which are produced by Ciba Specialty Chemicals Corporation), Lucirin TPO (produced by BASF Corporation), KAYACURE-DETX, KAYACURE-MBP, KAYACURE-DMBI, KAYACURE-EPA, KAYACURE-OA (which are produced by Nippon Kayaku Corporation), VICURE-10, VICURE-55 (which are produced by STAUFFER Co. LTD), TRIGONALP1 (produced by AKZO Co. LTD), SANDORY 1000 (produced by SANDOZ Co. LTD), DEAP (produced by APJOHN Co. LTD), QUANTACURE-PDO, QUANTACURE-ITX, QUANTACURE-EPD (produced by WARDBLEKINSOP Co. LTD), and the like.

[0057]

Further, in the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, various types of photosensitizer can be used in combination with the photopolymerization initiator. For example, amines, ureas, sulfur-containing compounds, phosphorus-containing compound, chlorine-containing compounds or nitriles, or alternatively the other

nitrogen compounds can be used as a photosensitizer.

[0058]

Specifically, for achievement of a high degree of curable properties, particularly preferable examples are one or a mixture of two or more selected from the group consisting of: 1-hydroxycyclohexyl phenyl ketone, 2-hydroxy-2-methyl-1-phenylpropan-1-one, 1-[4-(2-hydroxyethoxy)phenyl]-2-hydroxy-2-methyl-1-propan-1-one, thioxanthone and thioxanthone derivative, 2,2'-dimethoxy-1,2-diphenylethan-1-one, 2,4,6-trimethylbenzoyldiphenylphosphine oxide, bis(2,4,6-trimethylbenzoyl)phenylphosphine oxide, 2-methyl-1-[4-(methylthio)phenyl]-2-morpholino-1-propanone and 2-benzyl-2-dimethylamino-1-(4-morpholinophenyl)-butan-1-one.

[0059]

The photosensitizer can be used either alone or in combination of two kinds or more. The amount of the photosensitizer used is not particularly limited, but preferably ranges from 0.05 to 20 parts by mass, particularly preferably ranges from 0.1 to 10 parts by mass, with respect to 100 parts by mass of the actinic-energy-ray-curable resin composition for lens sheet use, for the purpose of maintaining satisfactory sensibility and preventing crystal precipitation, deterioration in physical properties of coating and the like.

[0060]

Further, when the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention is used to manufacture a lens sheet according to the present invention, the actinic energy ray such as ultraviolet light is often applied through a transparent substrate surface serving as a base. Therefore, a preferable photo(polymerization) initiator has the capability of absorbing light in the long-wavelength region. For example, a photo(polymerization) initiator making use of the photoinitiation capability in the wavelength range from 360nm to 450nm is desirably used. A photo(polymerization) initiator having a high degree of absorption properties has less stability even when the light has a wavelength of more than 450nm. For this reason, the lens sheet is required to be manufactured in the environment where light is

completely shielded, and therefore the handling is difficult. Note that when electron rays are used, these photo(polymerization) initiator and photosensitizer are unnecessary.

[0061]

When the resin composition is cured by use of electron rays, any apparatus equipped with a radiation source of various types of an electron accelerator, such as a Cockcroft Walton type, a Van de Graaff type, resonance transformer type insulating core transformer type, linear type, dynamitron type and radiofrequency type electron accelerator, which radiates electrons having energy of from 100keV to 1,000keV, preferably, from 100keV to 300keV. A preferable radiation dose typically is approximately from 0.5Mrad to 30Mrad.

[0062]

In the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, an ultraviolet absorber can be added as necessary in the cases when light resistance is required of the cured resin molded layer formed on the substrate, and the like. Further, when property modification of coating, coating adequacy, properties of removing from the mother mold are improved, it is possible to add a silicone additive, fluorine additive, anti-oxidant, rheology control agent, defoamer, mold release agent, silane coupling agent, antistatic additive, anti-fog additive, coloring material or the like.

[0063]

As the example of the silicone additive used is polyorganosiloxanes having a alkyl group or phenyl radical such as dimethylpolysiloxane, methylphenylpolysiloxane, cyclic dimethylpolysiloxane, methylhydrogenpolysiloxane, a polyether modified dimethylpolysiloxane copolymer, a polyester modified dimethylpolysiloxane copolymer, a fluorine modified dimethylpolysiloxane copolymer, and an amino modified dimethylpolysiloxane copolymer. Of these, the polyether modified dimethylpolysiloxane copolymer is preferable because it is outstanding in compatibility with the resin composition.

[0064]

As the examples of the mold release agent used are

alkylphosphoester, polyoxyalkylene alkylether phosphoester, alkylphosphoester salt, metallic soap, polymer soap, and the like. The polyoxyalkylene alkyl ether phosphoester of the above examples is preferable because it is outstanding in compatibility with the resin composition.

[0065]

As the examples of the ultraviolet absorber used are: triazine derivative, such as 2-[4-{(2-hydroxy-3-dodecyloxypropyl)oxy}-2-hydroxyphenyl]-4,6-bis (2,4-dimethylphenyl)-1,3,5-triazine, and 2-[4-{(2-hydroxy-3-tridecyloxypropyl)oxy}-2-hydroxyphenyl]-4,6-bis (2,4-dimethylphenyl)-1,3,5-triazine, and also 2-(2'-xanthenecarboxy-5'-methylphenyl)benzotriazole, 2-(2'-o-nitrobenzyloxy-5'-methylphenyl)benzotriazole, 2-xanthenecarboxy-4-dodecyloxybenzophenone, 2-o-nitrobenzyloxy-4-dodecyloxybenzophenone, and the like.

[0066]

As the examples of the anti-oxidizing agent used are a hindered phenol anti-oxidant, a hindered amine anti-oxidant, an organosulfur anti-oxidant, a phosphoester anti-oxidant, and the like.

[0067]

The amount of each of the foregoing various additives used preferably ranges from 0.01 to 5 parts by mass with respect to 100 parts by mass of the actinic-energy-ray-curable resin composition for lens sheet use including the additives because each additive within this range can exert sufficiently its effect and does not inhibit the ultraviolet curing.

[0068]

The actinic-energy-ray-curable resin composition for lens sheet use according to the present invention is a material suitable for the manufacturing of a lens sheet having a structure in which a molded layer performing a lens function and made of a cured resin material is provided on a plastic substrate. Most of all, when the resin composition is used to manufacture a lens sheet requiring transparency, the ingredients constituting the resin composition are desirably utilized in combination such that the transmittance of light of a wavelength

range of 400nm to 900nm becomes 80% or more, preferably, 85% or more in the cured material of 200±25μm thick.

[0069]

The actinic-energy-ray-curable resin composition for lens sheet use according to the present invention is a material suitable for various types of a lens sheet with an optical molded layer which is made of a cured resin material, has fine lens pattern and is provided on a plastic substrate.

[0070]

Fig. 1 illustrates a sectional view of an example of a Fresnel lens sheet using the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, and a transmission-type screen using the Fresnel lens sheet.

[0071]

The transmission-type screen 1 shown in Fig. 1 is composed of a Fresnel lens sheet 2 and a lenticular lens sheet 3. The Fresnel lens sheet 2 has a Fresnel-lens-shaped resin layer 4 provided on a plastic substrate 5 by curing the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention.

[0072]

The lens sheet of the present invention has a hardness at which the lens sheet is not deformed when a small pressure is applied to the lens layer and at which the lens sheet is not much stiff and can recover from its deformed shape in the use conditions even if deformation occurs when a large pressure is temporarily applied. Hence, in each of the fine shape units forming a lens, a compressive elasticity modulus around the center of the shape is preferably 700MPa to 1,600MPa.

[0073]

Further, the lens sheet of the present invention is not creep-deformed even when pressure is applied to the lens layer for long periods of time and is capable of recovering from its deformed shape after being released from the pressure applied in long time. Accordingly, the percentage of creep deformation around the center of the shape is preferably 20% to 40%.

[0074]

For the sake of reference, the values of the compressive

elasticity modulus and the percentage of creep deformation in the present invention are defined as values obtained from data concerning measurement made in conditions of embodiment examples, described later, by the application of the universal hardness test using a ultra microhardness tester (e.g. H-100 produced by Fischer Instruments K.K).

[0075]

As the examples of the plastic substrate used for the lens sheet according to the present invention are substrates made of an acrylate resin, a polystyrene resin, a polyester resin and a polycarbonate resin, and the like. Particularly, the substrate made of the acrylate resin having methyl methacrylate as the main ingredient and the substrate made of the polyester resin both are suitable for use because they exhibit their favorable adhesion to the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention.

[0076]

Further, the aforementioned transmission-type screen 1 can be provided by using a combination of the Fresnel lens sheet 2 with a lens sheet having another shape, other than with the lenticular lens sheet 3 shown in Fig. 1.

[0077]

As a method for manufacturing the Fresnel lens 2 by use of the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention are exemplified a method of infusing the resin composition into a mother mold for forming a Fresnel lens, then laminating a plastic substrate on the infused resin composition and applying pressure to make close contact between them in such a manner as to prevent the trapping of air, then applying the actinic energy ray such as ultraviolet light from the plastic substrate side to cure the resin composition, and then removing the cured resin composition from the mother mold for forming a Fresnel lens, and the like. Further, as a method of manufacturing the lenticular lens sheet 3 are exemplified a method of continuously infusing the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention into a roll-shaped mother mold for forming a lenticular lens, then continuously placing a plastic substrate

on close contact with the infused resin composition in such a manner as to prevent the trapping of air, then applying the actinic energy ray such as ultraviolet light from the plastic substrate side to cure the resin composition, and then removing the cured resin composition from the roll-shaped mother mold for forming a lenticular lens, and the like.

[0078]

The lens sheet according to the present invention has a lens surface formed by use of the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention. In consequence, the lens sheet is outstanding in adhesion to the plastic substrate, shape recovery properties, the mechanical strength, and moldability and exhibits a high refractive index. Hence, for example, when a transmission-type screen is made by use of the Fresnel lens sheet using the actinic-energy-ray-curable resin composition for lens sheet use according to the present invention, the screen has the features of improving the resistance properties to recovery from the contact pressure on the lenticular lens and the pressure applied in the assembly process performed after the television unit setting process, and of facilitating design relating to the handling in the screen setting process, that is, workability and assembly. Further, the screen has the feature of a high refractive index enabling the design of a shorter focus lens.

[0079]

[Examples]

Next, the present invention will be described in more detail using embodiment examples and comparison examples. It is needless to say that the present invention is not limited to these examples. Note that "part" and "%" used in the examples all are based on "mass" unless otherwise stated.

[0080]

Examples 1 to 6 and Comparison examples 1 to 3

Actinic-energy-ray-curable resin compositions for lens sheet use were prepared with the formulation shown in Table 1 and Table 2. The values of glass transition temperature (Tg) of the thermoplastic resin (d) were obtained from the data concerning measurements made by use of a differential scanning calorimeter [thermal analysis system

DSC220 produced by Seiko Instruments Corporation] on condition that a rate of temperature rise is 10°C/min. and measurement temperature ranges from -100°C to 150°C.

[0081]

[Table 1]

| Item | | Example | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| (a) | a-1 (part) | 38 | 35 | 35 | 35 | 38 | - |
| | a-2 (part) | - | - | - | - | - | 35 |
| (b1) | b1-1 (part) | 10 | 10 | 15 | 16 | 8 | 8 |
| (b2) | b2-1 (part) | 15 | 15 | 10 | 8 | 13 | 8 |
| (b3) | b3-1 (part) | 12 | 10 | 15 | 10 | 10 | 20 |
| (c) | c-1 (part) | 22 | 26 | 10 | 17 | 17 | 23 |
| | c-2 (part) | - | - | 12 | - | - | - |
| | c-3 (part) | - | - | - | 7 | 7 | - |
| (d) | d-1 (part) | 3 | 7 | 3 | 3 | 2 | 4 |
| | d-2 (part) | - | - | - | - | 1 | - |
| (e) | e-1 (part) | - | - | - | 4 | 4 | - |
| | e-2 (part) | - | - | - | - | - | 2 |
| Photo-initiator (part) | | 3 | 3 | 3 | 3 | 3 | 3 |

[0082]

[Table 2]

| Item | | Comparison example | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| (a) | a-1 (part) | - | 38 | 38 |
| | a-2 (part) | 35 | - | - |
| (b1) | b1-1 (part) | 10 | 25 | 25 |
| (b2) | b2-1 (part) | 10 | - | - |
| (b3) | b3-1 (part) | - | 12 | 12 |

| | | | | |
|---|---|---|---|---|
| (c) | c-1 (part) | 45 | 22 | 20 |
| | c-2 (part) | - | - | - |
| | c-3 (part) | - | - | - |
| (d) | d-1 (part) | - | 3 | 3 |
| | d-2 (part) | - | - | 2 |
| (e) | e-1 (part) | - | - | - |
| | e-2 (part) | - | - | - |
| | Photo-initiator (part) | 3 | 3 | 3 |

[0083]

<Footnotes of Table 1 and Table 2>

a-1: epoxy acrylate resulting from the reaction of acrylate acid with a bisphenol-A epoxy resin (epoxy equivalent 380g/eq).

a-2: epoxy acrylate resulting from the reaction of acrylate acid with a bisphenol-A epoxy resin (epoxy equivalent 635g/eq).

b1-1: ethylene oxide modified bisphenol-A diacrylate expressed by the general formula (1) wherein, R1, R2 are either hydrogen atoms and a mean value of m1+m2 is 4.

b2-1: ethylene oxide modified bisphenol-A diacrylate expressed by the general formula (2) wherein R3, R4 are hydrogen atoms and a mean value of n1+n2 is 10.

b3-1: tripropylene glycol diacrylate.

b3-2: diacrylate of polypropylene glycol (molecular weight: 400)

c-1: phenoxy ethyl acrylate.

c-2: phenoxydiethylene glycol acrylate.

c-3: 2-hydroxy-3-phenoxypropylacrylate.

d-1: polyurethane resin (aliphatic polyesterdiol/hexamethylene diisocyanate resin, weight mean molecular weight measured by GPC = 85,000, Tg=-49°C).

d-2: acrylate resin having methyl methacrylate as the main ingredient(weight mean molecular weight measured by GPC = 105,000, Tg=98°C).

e-1: triacrylate of polyhydric alcohol, with average 6 moles of propylene oxide being added to trimethylolpropane.

e-2: tri(acryloyloxyethyl) isocyanurate.

Photo-initiator: 1-hydroxycyclohexyl phenyl ketone.

[0084]

(Evaluation sample manufacturing)

A cured resin film for measurement use and a Fresnel lens sheet and base plate with a cured resin layer were manufactured by the following method.

(1) Manufacturing of cured resin film: an actinic-energy-ray-curable resin composition for lens sheet use was heated to 40°C, then was supplied between a chrome-plated metal plate and a transparent PET film before surface treatment, which then was adjusted in thickness. Then, by use of a high-pressure mercury lamp, ultraviolet light of 1000jm/cm$^2$ was applied from the transparent substrate side to cure the resin composition. Then, the actinic-energy-ray-curable resin composition layer is removed from the metal plate and the transparent substrate. Thus, the cured resin film having a smooth surface and a thickness of 200±25μm was manufactured.

[0085]

(2) Manufacturing of substrate with a cured resin layer: an actinic-energy-ray-curable resin composition for lens sheet use was heated to 40°C, then was supplied between a chrome-plated metal plate and a 10cm-long, 10cm-wide, 2mm-thick substrate made of a methyl methacrylate resin, which then was adjusted in thickness. Then, a high-pressure mercury lamp was used to apply ultraviolet light of 1000jm/cm$^2$ from the transparent substrate side to cure the resin composition. Then, the transparent substrate, together with the actinic-energy-ray-curable resin composition layer, is removed from the metal plate. Thus, the substrate with the 150±25μm thick cured resin film having a smooth surface being formed on the transparent substrate was manufactured.

[0086]

(3) Manufacturing of a Fresnel lens sheet: an actinic-energy-ray-curable resin composition for lens sheet use heated to 42°C was charged into the metal mold for forming a Fresnel lens. Then, while the temperature of the charged resin composite was being retained at 42°C, a 2-mm thick substrate made of a methyl methacrylate resin was laminated on the resin composite and then pressure is applied to them in such a manner as to prevent the trapping

of air. Then, ultraviolet light was applied to the resin composition on condition that the integral of the light volume is 2000mj/cm$^2$, and a peak illuminance is 250mW/cm$^2$, by use of a metal-halide-type ultraviolet lamp (produced by Nippon Denchi Corporation).

[0087]

(Evaluation method)

In accordance with the following measurement, test methods, evaluations of viscosity, refractive index, casting efficiency, shape reproducibility, adhesion, mold fracture and chipping, shape recovery properties and shape retention properties are performed on the obtained actinic-energy-ray-curable resin composition for lens sheet use, the obtained cured resin film, and the obtained Fresnel lens sheet and base plate with the cured resin layer. The evaluation results are shown in Table 3 and Table 4.

[0088]

[Table 3]

| Item | Example | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Viscosity (mPa.s) | 13300 | 19700 | 6920 | 9200 | 10630 | 6540 |
| Liquid Refractive index | 1.537 | 1.532 | 1.530 | 1.530 | 1.530 | 1.530 |
| Cured material refractive index | 1.560 | 1.555 | 1.552 | 1.554 | 1.553 | 1.553 |
| T(max) (°C) | 45 | 40 | 42 | 45 | 44 | 45 |
| Casting efficiency | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ |
| Shape reproducibility | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ |
| Adhesion | ◎ | ◎ | ◎ | ◎ | ◎ | ○ |
| Mold fracture and chipping | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ |
| Shape recovery properties | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ |
| Shape retention properties | ○ | ○ | ○ | ◎ | ◎ | ◎ |
| Compressive elasticity modulus | 1480 | 920 | 1130 | 1360 | 1200 | 1250 |

| | | | | | | |
|---|---|---|---|---|---|---|
| (MPa) | | | | | | |
| Percentage of creep deformation (%) | 28 | 35 | 30 | 23 | 29 | 25 |

[0089]

[Table 4]

| Item | Comparison example | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Viscosity (mPa.s) | 2500 | 14300 | 32300 |
| Liquid Refractive index | 1.543 | 1.535 | 1.533 |
| Cured material refractive index | 1.567 | 1.555 | 1.552 |
| T(max) (°C) | 33 | 53 | 54 |
| Casting efficiency | ◎ | ◎ | ◎ |
| Shape reproducibility | ◎ | ◎ | ◎ |
| Adhesion | ○ | ◎ | ◎ |
| Mold fracture and chipping | ◎ | ◎ | ◎ |
| Shape recovery properties | ◎ | △ | △ |
| Shape retention properties | × | △ | △ |
| Compressive elasticity modulus (MPa) | 620 | 1830 | 1950 |
| Percentage of creep deformation (%) | 43 | 9 | 5 |

[0090]

(1) Viscosity: viscosity measurement (mPa.s) was performed on the actinic-energy-ray-curable resin compositions for lens sheet use prepared with the formulations in Tables 1 and 2, at 25°C by an E-type rotational viscometer.

[0091]

(2) Refractive index: measurement was performed on liquid-form samples and cured samples. The refractive index of the liquid-form samples was measured at 25°C after a coating of the actinic-energy-ray-curable resin compositions for lens sheet use, which is used as the sample, was directly applied to a prism of an Abbe refractometer. Further, the refractive index of the cured samples was measured at 25°C of the sample temperature by use of the cured resin film as the sample, use of 1-bromonaphthalene as intermediate liquid

for making the sample adhere to the prism, and use of Abbe refractometer.

[0092]

(3) T(max): this is a temperature representing the maximum value of the mechanical loss tangent of the actinic-energy-ray-curable resin compositions for lens sheet use. The cured resin film was used as the sample and measured by use of a solid viscoelasticity measuring apparatus RSA-2 (produced by Rheometrics Corporation) employing a distortion control method on condition that a size is 6mm×35mm, a frequency is 1Hz, a load distortion is 0.05%, a rate of temperature rise is 3°C/min., and a measurement temperature is -50°C to 150°C. Then, data concerning the measurement within the temperature range from -30°C to 120°C out of the data concerning the above measurement was used to obtain the temperature T(max).

[0093]

(4) Casting efficiency: the degree of difficulty in performing the process of supplying the actinic-energy-ray-curable resin composition for lens sheet use into between the metal mold for forming a Fresnel lens and the acrylate resin plate in the manufacturing process for the Fresnel lens sheet is determined. Good casting efficiency is represented by ◎ and failed casting efficiency is represented by ×.

[0094]

(5) Shape reproducibility: in the manufacturing process for the Fresnel lens sheet, a visual inspection was made on the appearance of the Fresnel lens sheet which had been removed from the metal mold for forming a Fresnel lens. The Fresnel lens sheet with the uniform surface shape without chipping is represented by ◎ and the Fresnel lens sheet having the chipped shape because of occurrence of bubbles in the resin, the state of no resin reaching the intricate details of the mold is represented by ×.

[0095]

(6) Adhesion: the base plate with the cured resin layer was used to measure the adhesion between the base plate and the resin layer in conformity with JISK5600-5-6. The case when the grid pattern completely remained is represented by ◎. The case when the grid pattern remained at a ratio of (95 to 99)/100 is represented by ○. The

case when the grid pattern remained at a ratio of (80 to 94)/100 is represented by △. The case when the grid pattern remained below this ratio is represented by ×.

[0096]

(7) Mold fracture and chipping: a precision handcutter KPS3002 (produced by Sankyou Corporation) was used to cut the base plate with the cured resin layer from the cured resin layer side. In this cutting process, the case of no damage to the cured resin layer or the base plate is represented by ◎, and the case of occurrence of fracture and chipping is represented by ×.

[0097]

(8) Shape recovery properties: the base plate with the cured resin layer was used. By the application of the universal hardness test using an ultra microhardness tester (H-100 produced by Fischer Instruments K.K), the shape recovery properties were evaluated, according to the following steps (i) to (v). As the indenting too, the ball indentor having a radius R of 0.2mmø made of tungsten carbite was used.

[0098]

(i) At 40°C, the load is increased to a compression load in which the penetration depth (=the mount of deformation) reaches 15μm to 20μm for 10 seconds.

(ii) The above compression load value is retained for 60 seconds.

(iii) The load value is decreased to 0.4mN (=minimum load of the tester) for four seconds.

(iv) The load value 0.4mN is retained for 60 seconds to cause a decrease in the penetration depth.

(v) The above steps (i) to (iv) are repeated three times, and then the mean value of the recoveries is obtained.

The case of less than 3μm of an average penetration depth after recovery is represented by ◎. The case of less than 3μm and 5μm or more is represented by ○. The case of 5μm or more and less than 8μm is represented by △. The case of 8μm or more is represented by ×.

[0099]

(9) Shape retention properties: a 10cm×10cm test specimen, which had been cut out from a corner of the Fresnel lens sheet, was

horizontally placed on the smooth metal plate with the cured resin layer side up. A weight having the flat bottom was placed on a central portion of the test specimen. The load of $20g/cm^2$ was applied at 40°C for 7 days. Then, after the temperature of the test specimen was decreased back to 25°C, the load was removed. Visual inspections are conducted for the presence of deformation marks on the Fresnel lens sheet after a lapse of 30 minutes and 24 hours from the load release. The case when any deformation mark was not found after a lapse of 30 minutes is represented by ◎. The case when the deformation mark was slightly found after 30 minutes but was not fount after the 24 hours is represented by ○. The case when the deformation mark was slightly found after 24 hours is represented by △. The case when the deformation mark was clearly found after 24 hours is represented by ×.

[0100]

(10) Compressive elasticity modulus: the Fresnel lens sheet was used. By the application of the universal hardness test using an ultra microhardness tester (H-100 produced by Fischer Instruments K.K), the compressive elasticity modulus were measured, according to the following steps (i) to (v). A load-dependence curve obtained in the measurement is shown in Fig. 2. Deformation occurs when the load is gradually increased from load=zero (point A) up to a set load value, and the penetration depth of the indentor increases (point B). After the load has been increased to the set load value, if the load value is retained without change for a predetermined period of time, the penetration depth is continuously increased during the period due to creep deformation (point C). Then, when the load is gradually decreased up to a minimum load value, the lens sheet recovers from the deformation and the penetration depth of the indentor decreases (point D). If the minimum load value is retained without change for a predetermined period of time, the lens sheet further recovers from the deformation during the period (point E).

(i) At 23°C, the compression load is increased from zero to 20mN for 10 seconds.

(ii) The above compression load value is retained for 60 seconds to cause occurrence of creep deformation.

(iii) The load value is decreased to 0.4mN (=minimum load of

the tester) for four seconds.

(iv) The load value 0.4mN is retained for 60 seconds to cause a decrease in the penetration depth.

(v) The above steps (i) to (iv) are repeated three times. A load-dependence curve of the penetration depth is obtained in each cycle, then a compressive elasticity modulus (unit: MPs) is obtained from each curve and then the mean value of the compressive elasticity modulus is calculated.

[0101]

Note that as the indenting too, the ball indentor having a radius R of 0.2mm made of tungsten carbite was used. As illustrated in Fig. 3, portions of the lens sheet measured by the ball indentor are preferably around a center portion of each of lens surfaces constituting the Fresnel lens as indicated with 2c, 2c′ and 2c″ in Fig. 3. Assuming that the interval between the adjacent concave portions on the lens surfaces is a pitch P, the preferable portion is around a position corresponding to P/2.

[0102]

The compressive elasticity modulus (E) is calculated from the following equation.

$$E=1/\{2\times[hr(2R-hr)]^{1/2}\times H\times(\Delta H/\Delta f)-(1-\nu_{WC})/E_{WC}\}$$

Where, hr : the penetration depth at a point of intersection of the tangent line to the penetration depth curve when the load is decreased and the axis of the penetration depth (transverse axis) (unit: mm),

R: the radius of the ball indentor (R=0.2mm),

H: a maximum value of the penetration depth h (unit:mm),

$\Delta H/\Delta f$: a reciprocal of the slope of the tangent line to the penetration depth curve when the load is decreased,

$\nu_{WC}$: a Poisson's ratio of tungsten carbite ($\nu_{WC}=0.22$), and

$E_{WC}$: a coefficient of elasticity of tungsten carbite ($E_{WC}=5.3\times10^5 N/mm^2$).

[0103]

(11) Percentage of creep deformation: the Fresnel lens sheet was used. By the application of the universal hardness test using an ultra microhardness tester (H-100 produced by Fischer Instruments K.K), the percentage of creep deformation was measured through the

same steps as those for the measurement of the compressive elasticity modulus.

The percentage of creep deformation (C) is calculated from the following equation.

$$C=[(h2-h1)/h1]\times 100$$

Where, h1: the penetration depth when the load reaches a set test load (=20mN), and

h2: the penetration depth when the load is retained for a predetermined time (60 seconds) (point C in Fig. 2).

[0104]

[Advantageous Effects of the Invention]

With the lens-sheet-application actinic-energy-ray-curable resin composition according to the present invention, it is possible to provide a lens sheet having outstanding properties of adhesion to a plastic substrate, shape recovery, mechanical strength and moldability, and particularly a high refractive index.

Accordingly, when this actinic-energy-ray-curable resin composition is used to manufacture a transmission type screen, the transmission type screen has the advantageous features of improving resistance properties to recovery from the contact pressure on a lenticular lens and the pressure applied in the assembly process performed after the television unit setting process, to facilitate handling in the screen setting process, that is, a design relating to workability and assembly. Further, a high refractive index allows the design of a shorter focus lens.

[BRIEF DESCRIPTION OF DRAWINGS]

[FIG. 1]

Fig. 1 is a sectional view illustrating an example of a transmission-type screen using a Fresnel lens sheet.

[FIG. 2]

Fig. 2 is a diagram illustrating an example of a load-dependence curve obtained by measuring a compressive elasticity modulus when a Fresnel lens sheet is used.

[FIG. 3]

Fig. 3 is a diagram illustrating part of the Fresnel lens sheet acted upon by a ball indentor when the compressive elasticity modulus

is measured.

[EXPLANATION OF REFERENCE NUMERALS]

1: TRANSMISSION-TYPE SCREEN LENS

2: FRESNEL LENS SHEET

3: LENTICULAR LENS SHEET

4: RESIN LAYER OF FRESNEL LENS SHAPE

5: PLASTIC SUBSTRATE

POINT A: POINT OF LOAD=ZERO

POINT B: POINT AT WHICH LOAD IS INCREASED TO SET VALUE

POINT C: POINT AT WHICH SET LOAD HAS BEEN MAINTAINED FOR PREDETERMINED TIME PERIOD

POINT D: POINT AT WHICH LOAD IS DECREASED TO MINIMUM

POINT E: POINT AT WHICH MINIMUM LOAD HAS BEEN MAINTAINED FOR PREDETERMINED TIME PERIOD

6: BALL INDENTOR

P: INTERVAL BETWEEN CONCAVE PORTIONS OF ADJACENT LENS SURFACES

[TITLE OF DOCUMENT] ABSTRACT

[Abstract]

[Object of the Invention] An actinic-energy-ray-curable resin composition for a lens sheet, which is outstanding in adhesion to a plastic substrate, shape recovery properties, mechanical strength and moldability, and shows a high refractive index, and a lens sheet using this resin composition are provided.

[Means for Attaining the Object] An actinic-energy-ray-curable resin composition for a lens sheet, comprising: an epoxy (meth)acrylate (a); a bifunctional (meth)acrylate (b); a monofunctional (meth)acrylate (c); and a thermoplastic resin (d), wherein the ingredient (b) comprises: di(meth)acrylate (b1) of alkylene oxide modified bisphenol A with an average number of added moles of alkylene oxide ranging from 1 to 5; di(meth)acrylate (b2) of alkylene oxide modified bisphenol A with an average number of added moles of alkylene oxide ranging from 8 to 20; and a (meth)acrylate (b3) of an aliphatic dihydric alcohol having an alkylene oxide structure, and a lens sheet using the resin composition.

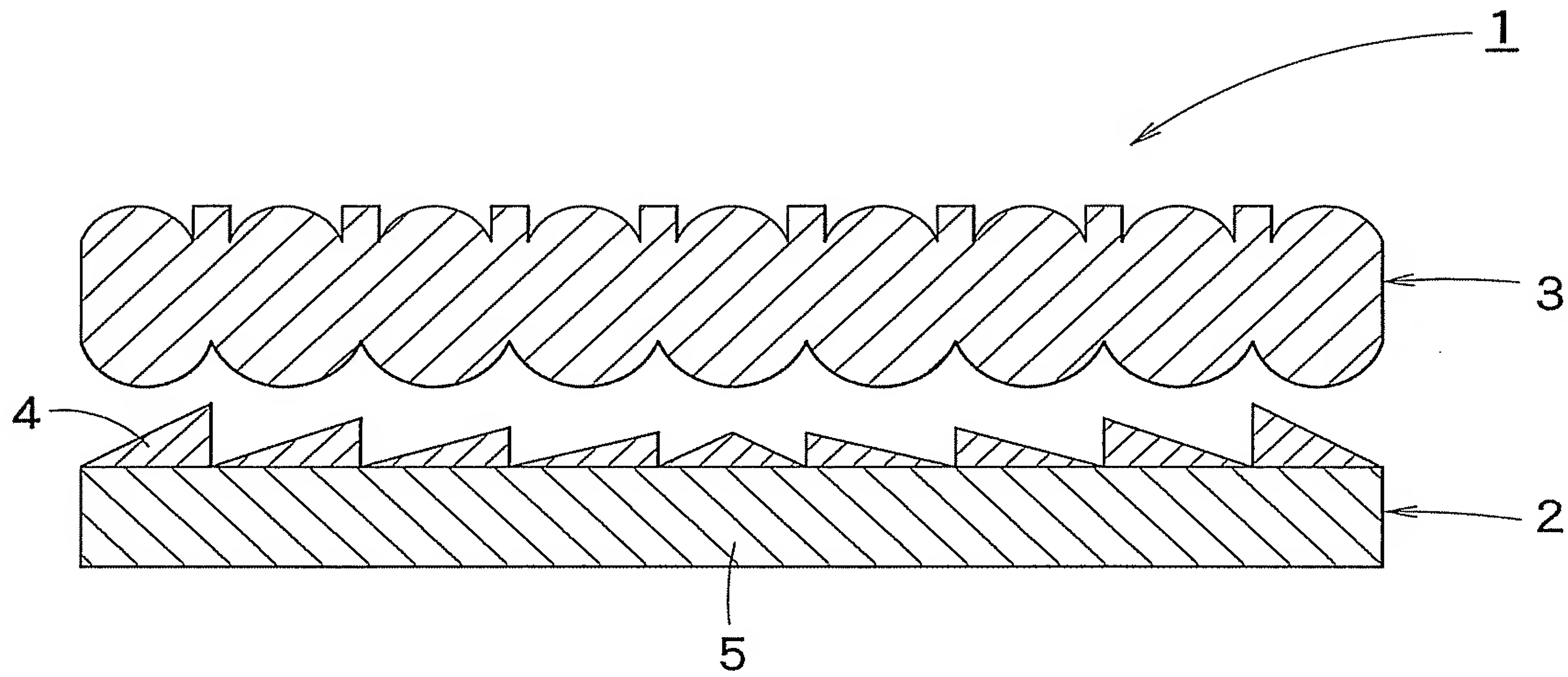

1
3
4
2
5

FIG. 1

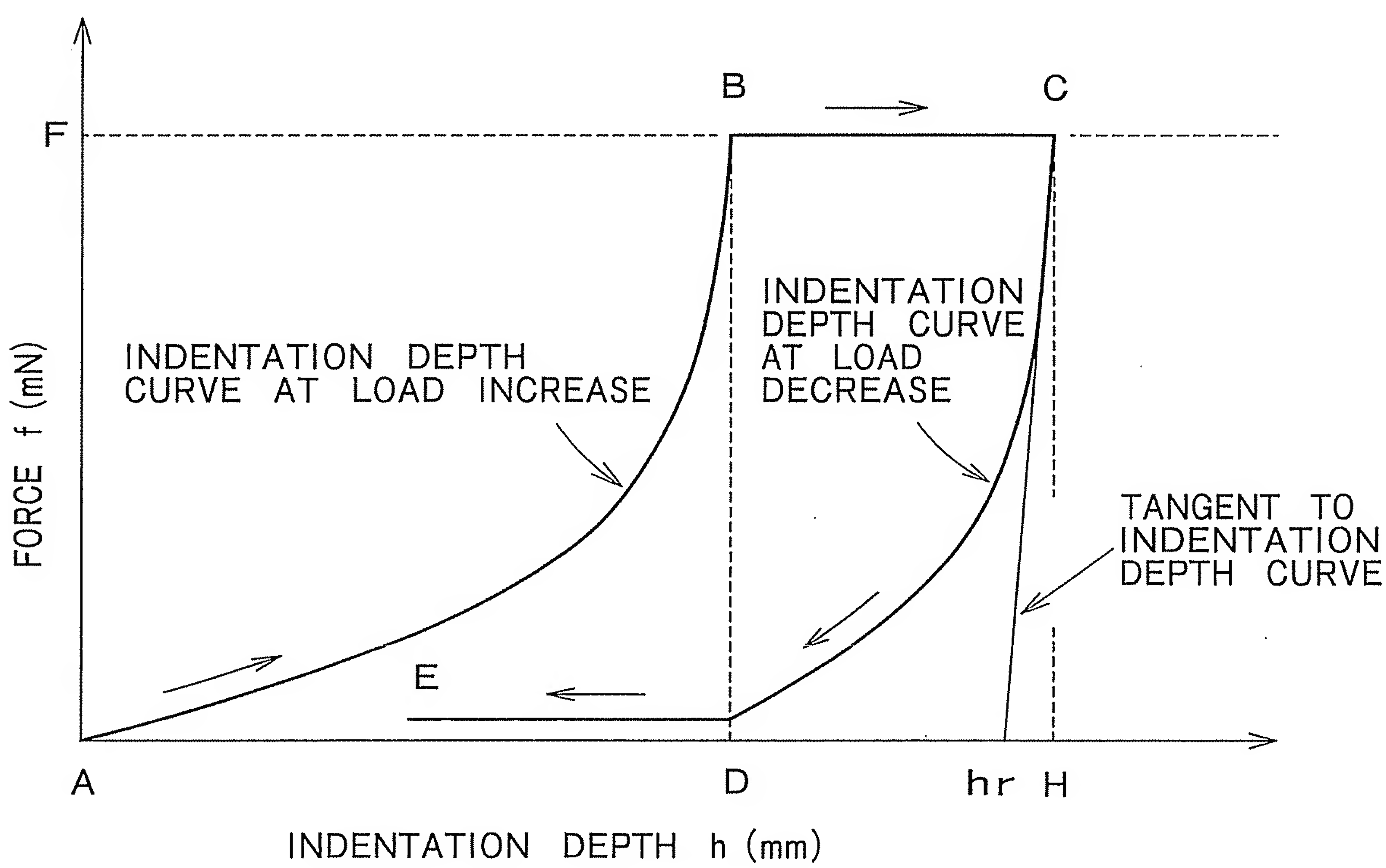

B
C
F
INDENTATION DEPTH CURVE AT LOAD INCREASE
INDENTATION DEPTH CURVE AT LOAD DECREASE
TANGENT TO INDENTATION DEPTH CURVE
FORCE f (mN)
E
A
D
hr
H
INDENTATION DEPTH h (mm)

FIG. 2

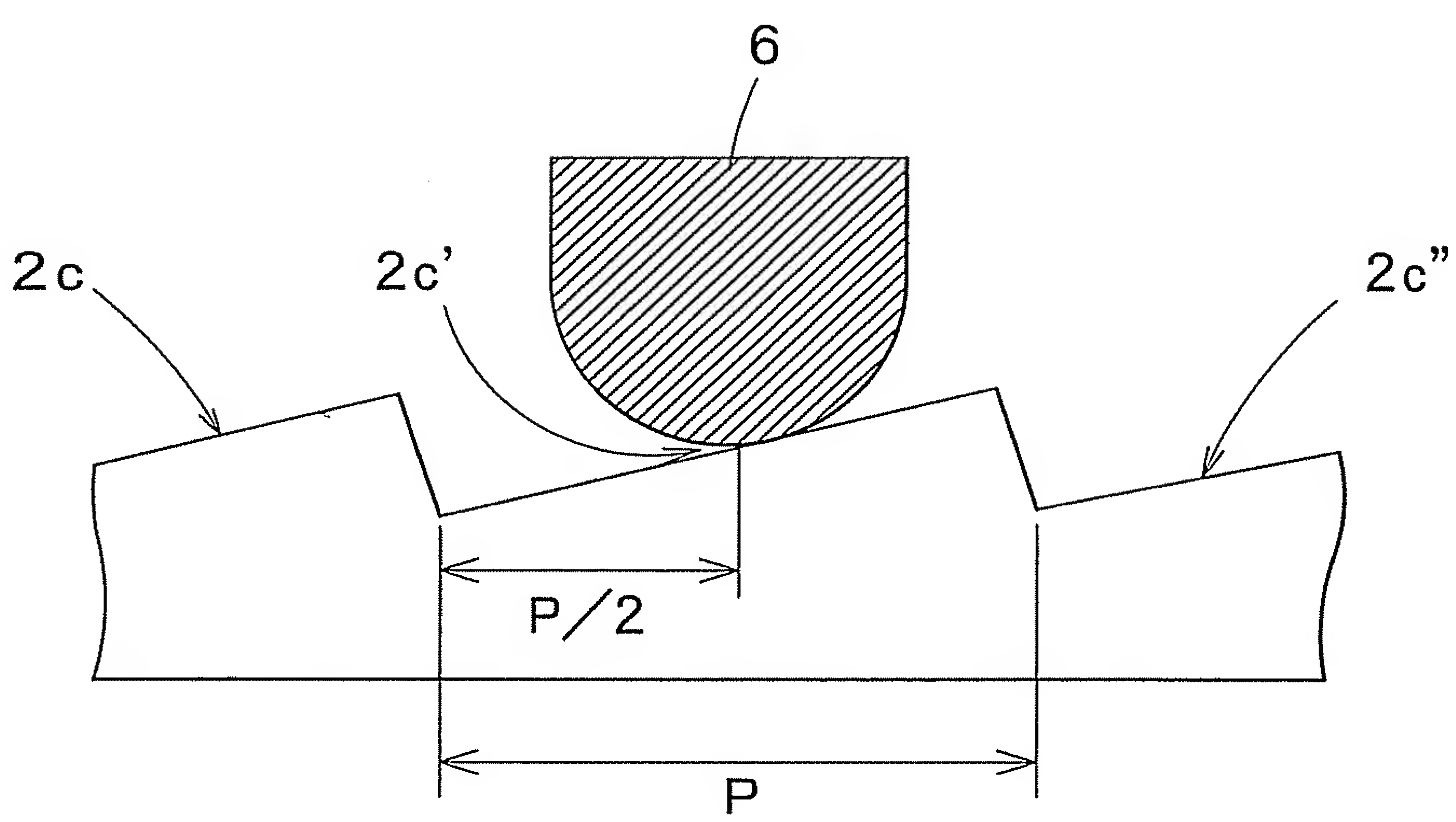



FIG.3